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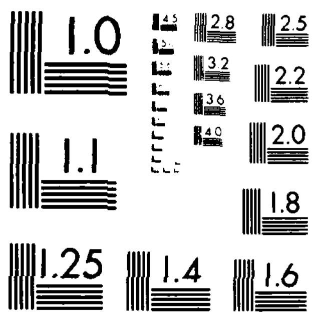

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Monterey, California

INTERANNUAL VARIABILITY IN SEA-SURFACE

TEMPERATURE AT ONE LOCATION ALONG

THE CENTRAL CALIFORNIA COAST

by

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May 1984

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Sea surface temperature (SST) since March 1, 1971 at Granite Canyon, just north of Pt. Sur, California, are examined for interannual variability. Each of four El Niño episodes occurring over the past 13 years can be easily detected in the raw data. Annual mean temperatures are significantly higher during the El Niño years. The 1982-83 El Niño episode was more intense than the previous episodes; temperatures were as much as 5C above normal during the episode and it lasted for about 20 months. Major abrupt decreases in SST were frequently observed during the spring. These events are identified as

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the spring transition to coastal upwelling and appear to be most intense following El Niño episodes. Empirical Orthogonal Function analysis of the data indicates that maximum variability in SST's occurs between October and February and that it coincides with the four El Niño episodes occurring over the past 13 years.

ABSTRACT

Sea surface temperature (SST) since March 1, 1971 at Granite Canyon, just north of Pt. Sur, California, are examined for interannual variability. Each of four El Niño episodes occurring over the past 13 years can be easily detected in the raw data. Annual mean temperatures are significantly higher during the El Niño years. The 1982-83 El Niño episode was more intense than the previous episodes; temperatures were as much as 5C above normal during the episode and it lasted for about 20 months. Major abrupt decreases in SST were frequently observed during the spring. These events are identified as the spring transition to coastal upswelling and appear to be most intense following El Niño episodes. Empirical Orthogonal Function analysis of the data indicates that maximum variability in SST's occurs between October and February and that it coincides with the four El Niño episodes occurring over the past 13 years.

Interannual Variability in Sea-Surface Temperature
at One Location Along the Central California Coast

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Sea-surface temperatures (SSTs) have been acquired since March 1,1971 at Granite Canyon, a location 11 km north of Pt. Sur and about 25 km south of Monterey (FIGURE 1). This location has a good exposure to the deep ocean with the continental shelf extending only [illegible] km offshore. The observations are taken daily at approximately 08[illegible] local time. Temperatures are read to the nearest 0.1C using a calibrated VWR [illegible] thermometer. Measurement accuracy is about ± 0.2C (SIO Reference [illegible]).

FIGURE 2 shows the time-series of daily SST at Granite Canyon starting on March 1, 1971 and ending on January [illegible], 198[illegible]. Each El Niño episode occurring within the past 13 years is indicated by a vertical arrow (the 1972-73, 1976-77, 1979-80, and the 1982-83 episodes). Even the relatively weak El Niño episode of 1979-80 can be easily identified in the raw data. Abrupt decreases in temperature can also be seen in [illegible], 19[illegible], 1980 and 1981 and correspond to the spring transitions to coastal upwelling. The spring transition is a major event along the coasts of California and Oregon that signals the seasonal change from non-upwelling to upwelling conditions. This transition is not always distinct, but in the years [illegible] can be uniquely identified, it is apparently most intense following [illegible] episodes.

A smoothed version of the Granite Canyon time-series was produced using a cosine filter with 101 weights ([illegible]). In, the 1972-73, 1976-77, and

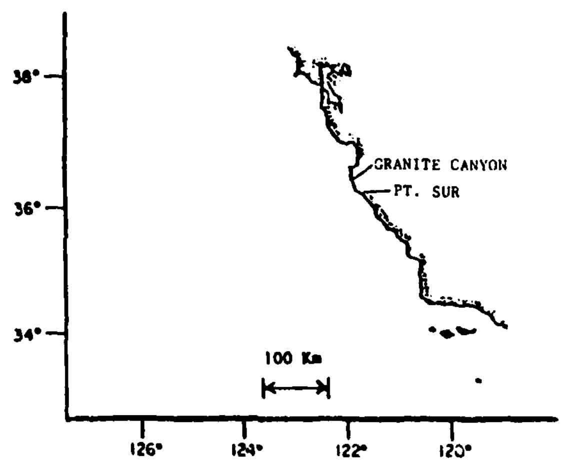

FIGURE 1
Central California coast showing the location of Granite Canyon. This location is 11 Km north of Pt. Sur and about 25 Km south of Monterey.

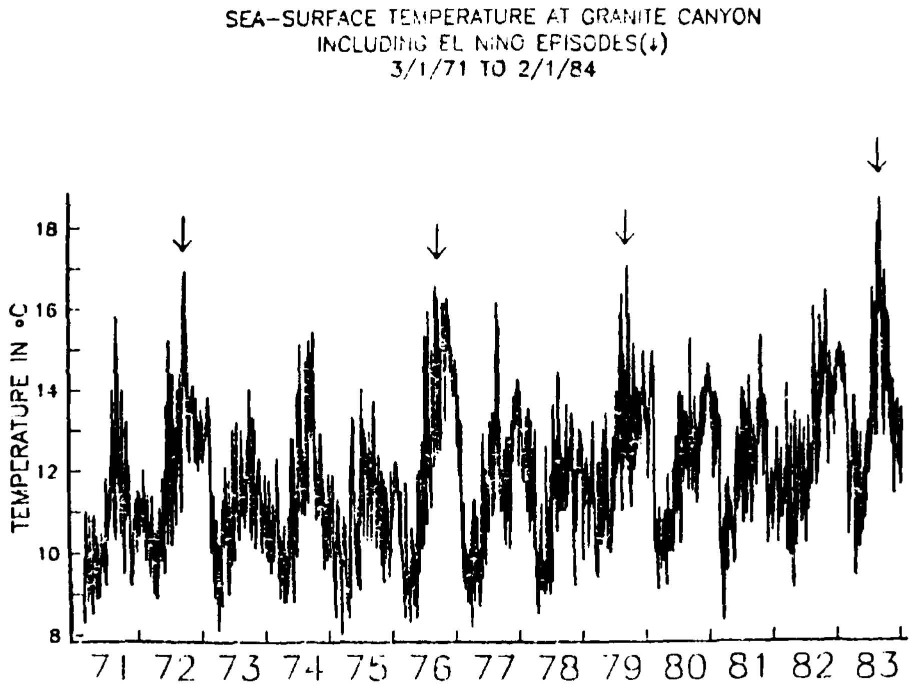

FIGURE 2
Sea-surface temperature (SST) time-series at Granite Canyon. Daily observations of SST span the period from March 1, 1971 to February 1, 1984. The 1972-73, 1976-77, 1979-80 and 1982-83 El Nino episodes are indicated.

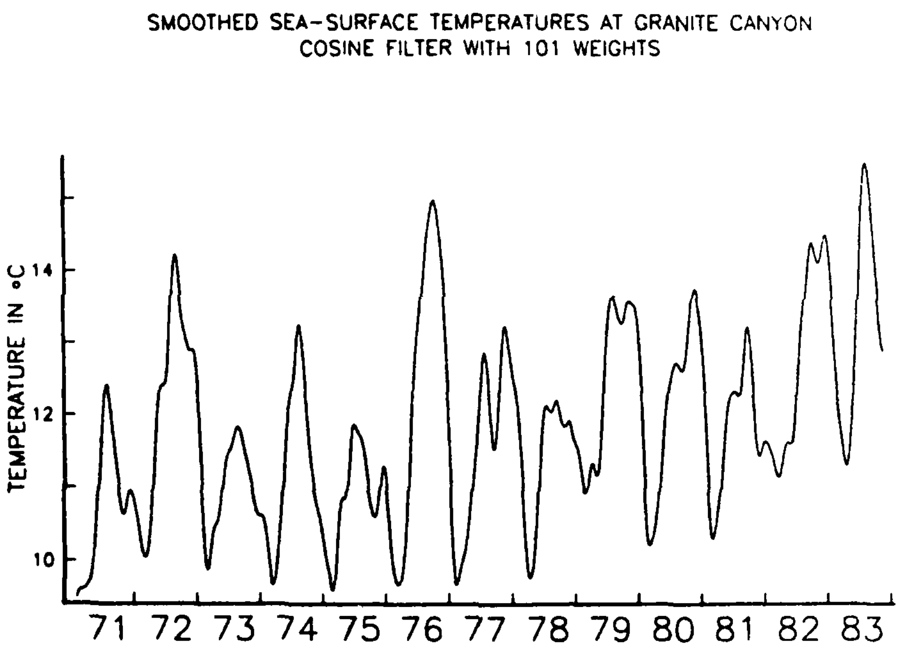

FIGURE 3
Sea-surface temperatures at Granite Canyon were smoothed using a cosine filter with 101 weights.

1982-83 El Niño episodes can be readily identified. However, the few isolated peaks in SST associated with the 1979-80 El Niño have been suppressed making this episode more difficult to identify. Generally warmer SSTs during the periods of seasonal upwelling are also seen starting in 1979. During the spring and summer of 1983, coastal upwelling was less apparent than usual for at least two reasons. First, the accumulation of warm water near the coast associated with the most recent El Niño episode prevented the local winds from bringing significantly cooler water to the surface. Second, the subtropical high-pressure cell which is primarily responsible for producing upwelling-favorable winds along the central California coast during spring and summer was located much farther west than usual resulting in coastal winds which were often weak and variable.

The quantized data are shown as a scatter plot of temperature versus time in FIGURE 4. A least-squares linear trend has also been fitted to the data. The linearly approximated temperature rises from 10.9 to 12.5C over 12 years. A separate analysis of these data has shown that the slope associated with this increase in temperature is statistically significant (Breaker et al., 1983). The solid circles in this figure represent the average temperature calculated from March through February, for each year in the series. The annual mean temperatures, are significantly higher (0.5 to 1.0C) during the years associated with each of the El Niño episodes.

Of particular interest is the 1982-83 El Niño because of its intensity and duration. FIGURE 5 shows a comparison of SSTs at Granite Canyon starting on January 1, 1982 and ending on January 1, 1984. The solid curve (smoothed slightly) represents a 12-year annual mean which has been repeated to span the

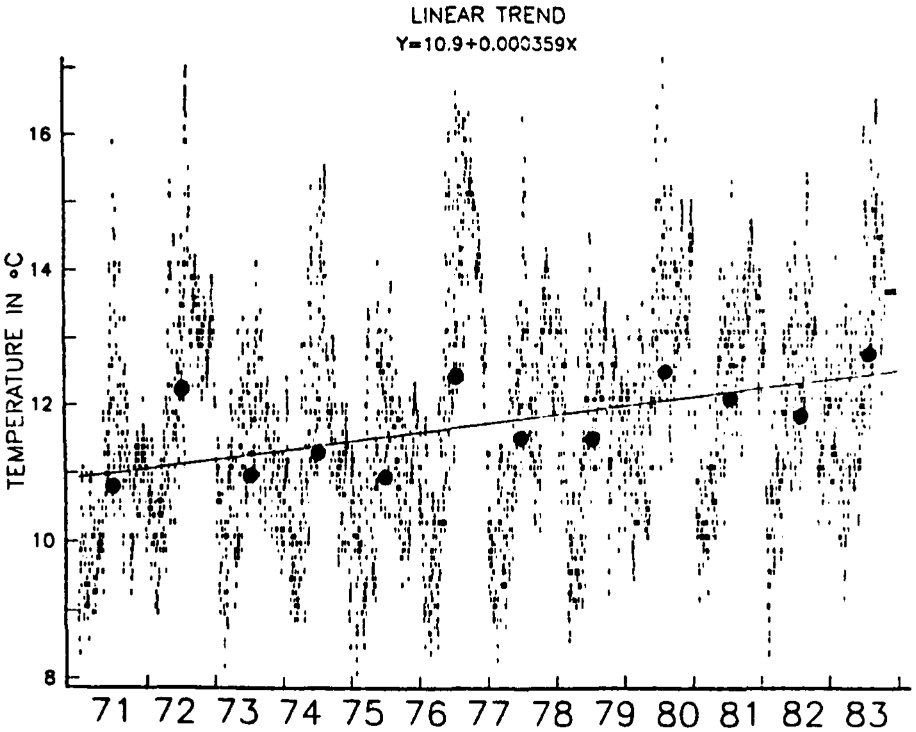

FIGURE 4
Individual observations are shown for the 12-year period starting on March 1, 1971. A least squares linear trend has been fitted to the data. The solid circles represent mean values for each year.

TWO-YEAR COMPARISON OF SEA-SURFACE TEMPERATURES
AT GRANITE CANYON

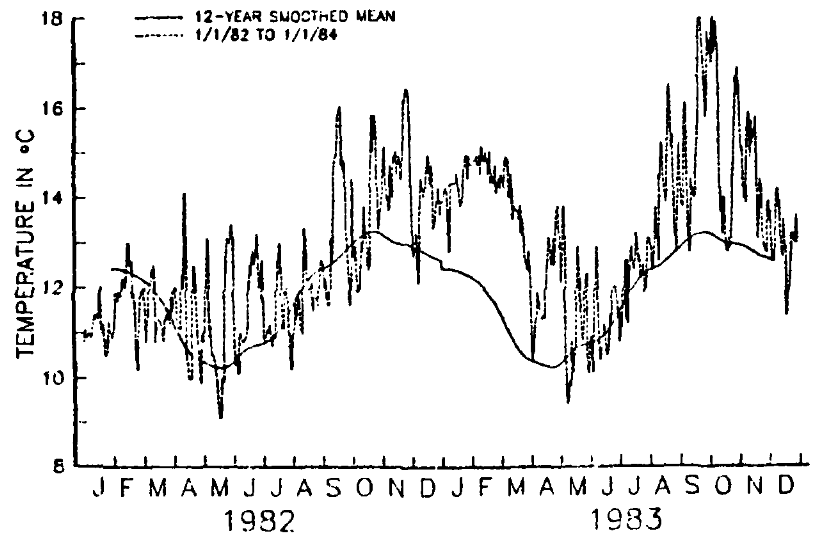

FIGURE 5
A comparison of smoothed mean SSTs and the original data from January 1, 1982 to January 1, 1984.

two-year period. The dashed curve represents the raw data during the same period. Above average temperatures persisted for approximately 20 months starting in April of 1982. By comparison, the significantly higher temperatures associated with the 1972-73 and 1976-77 El Niño's lasted for approximately 12 months or less. During September and October of 1983, temperatures were almost 5C above average. Temperatures were generally further above average during fall and winter in 1982, and during late summer and fall in 1983. By December 1983, temperatures had returned close to expected values.

Major abrupt decreases in SST occur between February and April in at least 6 out of the 13 years. These events have been identified as the spring transition to coastal upwelling. The time scale associated with these seasonal transitions is of the order of one week. FIGURE 2 suggests a tendency for the most intense spring transitions to follow El Niño episodes. The 1972-73, 1976-77, and 1979-80 episodes have been replotted in expanded form in FIGURE 6 to examine this tendency in more detail. The higher-than-average winter SSTs associated with these episodes are followed by a relatively intense spring transition in each case. McLain and Thomas (1983) have also observed that there is a tendency for major spring transitions to follow El Niño episodes.

The raw SST data also suggest that El Niño influence is mainly seasonal. In particular, higher-than-average SSTs associated with El Niño episodes tend to occur during fall and winter. This observation is consistent with intensified poleward flow in the California Countercurrent. To examine this tendency in greater detail, a two-way layout of the data has been constructed.

Monthly means over the entire 13-year period were plotted by month and year, (FIGURE 7). Values of 13C or greater are contoured with solid lines and lesser values with dotted lines. Relatively high values generally coincide with the El Niño episodes. The higher values also tend to occur between September and February. The monthly means were averaged across months to provide a one-dimensional summary plot (bottom of FIGURE 7). From 1972 to 1984, higher annual mean temperatures occur during the El Niño episodes. Also there is a systematic increase in overall mean temperature starting in 1976. According to Quinn and Neal (1983), generally higher SSTs have also been observed along the coast of South America since 1976. They attribute this increase in SST to below normal pressures in the southeast Pacific subtropical high and an associated weakening of the southeast trade winds. It is possible that the warmer SSTs observed along the central California coast are related to the same sequence of events. The monthly means were also averaged across years to provide another summary plot (right side of Figure 7). This summary plot reveals an annual cycle with a range of about 3C (temperature values not shown).

An Empirical Orthogonal Function (EOF) analysis of the Granite Canyon time-series was also undertaken. Prior to calculating EOFs however, the linear trend shown in FIGURE 4 was removed. An annual mean cycle was then calculated and removed from the detrended data. A 12 (year) X 365 (day) data matrix was then formed from the resulting series. The first EOF and the associated principal components are shown in FIGURE 8. The first EOF (smoothed slightly) accounts for 33.3% of the total variance in the data. From this primary mode of variation it is clear that most of the variability occurs between October and February in reasonable agreement with the results

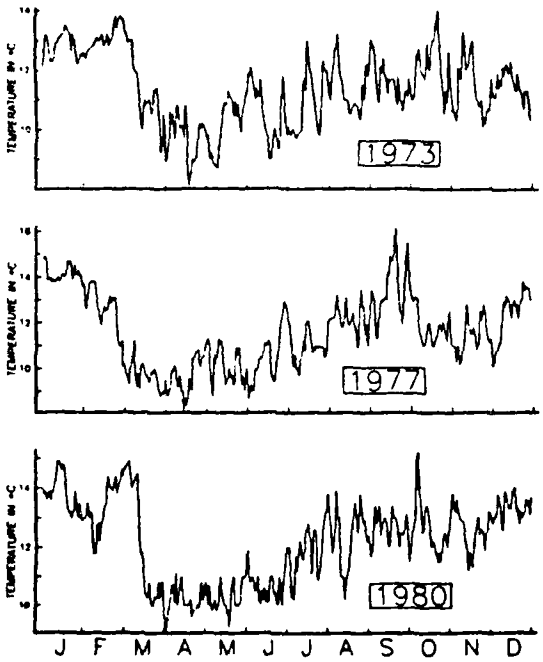

FIGURE 6
Spring transitions at Granite Canyon following El Nino episodes.

TWO-WAY LAYOUT OF MONTHLY MEANS(1971-1984)

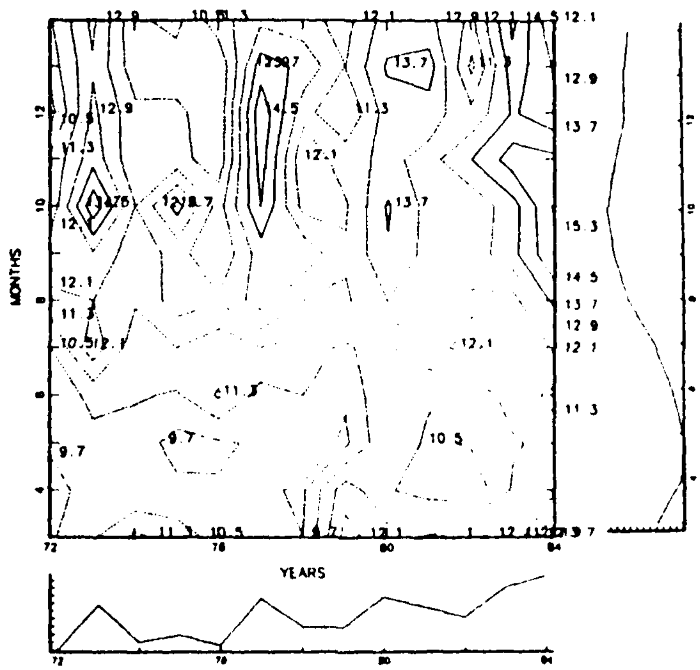

FIGURE 7
Two-way layout of monthly mean SSTs. Monthly values,averaged across months, are plotted along the bottom. Monthly values, averaged across years, are plotted along the right side. The range of temperatures in each case is approximately 3°C.

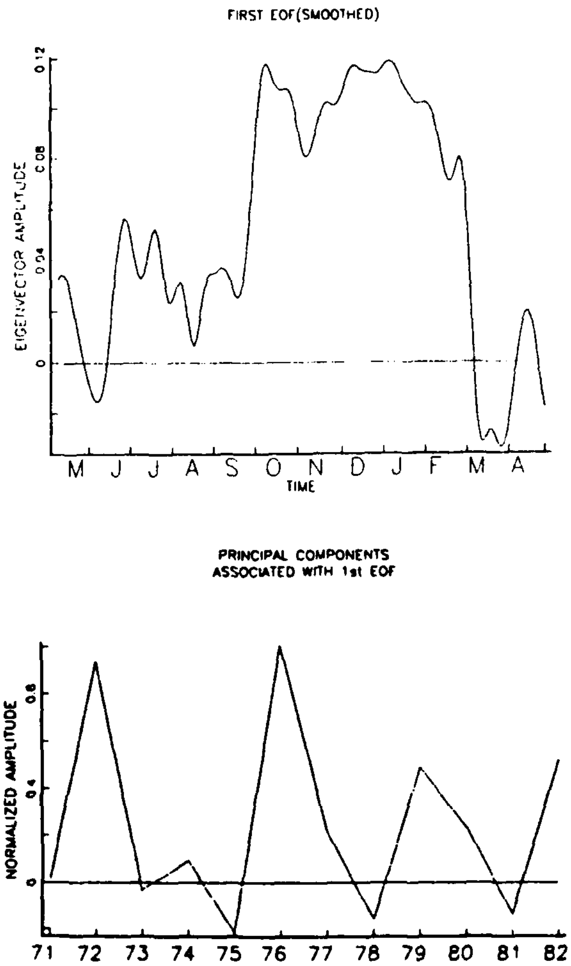

FIGURE 8

The first Empirical Orthogonal Function (EOF) and associated principal components for the Granite Canyon SSTs. A long-term linear trend and a mean annual cycle were removed prior to the EOF calculations.

from the previous two-way layout. That this variability is mainly associated with the various El Niño episodes is clearly evident from the sequence of principal components.

Sea-surface temperature appears to be a sensitive indicator of El Niño influence along the central California coast. During the past 13 years, four El Niño episodes were identified in the time-series of SST at Granite Canyon. Detection of these episodes at this latitude was not a problem. Due to their frequency of occurrence, intensity, and duration, these episodes must be considered to be a major source of interannual variability along the central California coast. Further work is needed to characterize these episodes and their influence along the California coast, and more generally along the coast of North America.

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